AQMD Contract #02161 *December 2002*

Develop Low-NOx 6.0L Natural Gas Engine and Chassis

Contractor
TeleflexGFI Control Systems L.P.
Bodycote Material Systems Inc. (subcontractor)
Englehard Corporation (subcontractor)
General Motors Corporation (subcontractor)

Cosponsors
Bodycote Material Systems Inc. (subcontractor)
Englehard Corporation (subcontractor)
General Motors Corporation (subcontractor)

Project Officer
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Background

The need for medium and heavy duty vehicles for small transit, delivery vehicles and shuttle services is increasing. CNG vehicles have demonstrated low emissions but have had the potential for even lowe emissions, particularly Nitrogen Oxides (NOx). The emissions standards for smaller vehicles are ever decreasing, and the intention is for larger vehicles (particularly SUV's and larger passenger vehicles) to follow suit.

The Department of Energy (DOE)/National Renewables Energy Laboratory (NREL) has initiated a program called the "Next Generation of Natural Gas Vehicles" (NGNGV). One of the purposes of this program is to develop a new medium duty compressed natural gas (CNG) vehicle with potential for early commercialization starting in 2004, and having NOx emissions at or below 0.5g/bhp-hr and PM emissions at or below 0.1g/bhp-hr. In 2007, the goal is to have NOx emissions below 0.2g/bhp-hr in order to meet the EPA's standards.

Project Objective

The project objective is to develop a low-NOx General Motors (GM) CNG medium duty engine which will have NOx emissions at or below 0.5 g/bhp-hr. The goal is to be achieved primarily through improved catalyst technology.

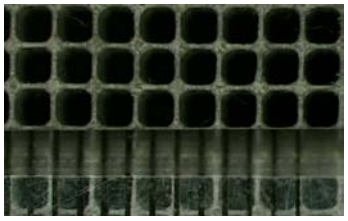
Technology Description

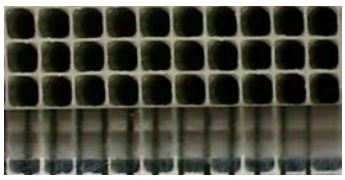
After completion of baseline emissions testing, several options for advanced catalyst designs have been conceived:

1. Substrate cell density change on under-floor (U/F) catalysts, which will provide enhanced residence time needed for conversion.
2. Wash-coat technology upgrade – tri-metal with low and high Palladium (Pd) to enhance low temperature performance.
3. Move the catalysts closer to the exhaust manifolds to allow for quicker heat up.
4. Addition of close-coupled catalysts to existing catalyst setup, with upgraded substrate cell density.

After extensive discussion between GFI and the Englehard Corporation, Englehard developed three different catalyst models for evaluation:

1. 600cpsi/3.5 mil wall "NEX 311H1" with 30g/ft^3 Pt/Pd/Rh in a 3/0/1 ratio. (Current catalyst cell density is 350 cpsi/5.5 mil wall)
2. 600cpsi/3.5 mil wall "OEX-101B" with 30g/ft^3 Pt/Pd/Rh in a 1/2/1 ratio.
3. 600cpsi/3.5 mil wall "OEX-101B" with a 45g/ft^3 Pt/Pd/Rh in a 1/2/1 ratio.


Standard 350 cpsi


New 650 cpsi

Catalyst Sections (cpsi: cells per square inch)

Status

TeleflexGFI Control Systems L.P. has completed all emissions testing and driveability evaluations. Due to very low baseline emissions results, the goal of

achieving 0.5 g/bhp-hr NOx was lowered to 0.2 g/bhp-hr and attained. The final selected catalyst underwent a driveability evaluation on a vehicle without any problems.

Results

The emissions tests that were conducted include Heavy Duty Transient (HDT) cycles recorded on a second-by-second basis for emissions components at the entrance and exit of the catalysts, catalyst temperature traces, air fuel ratios, and exhaust flow rates as well as a number of other engine and performance parameters. In addition, catalyst efficiency tests were conducted to determine the engine conditions in which the catalysts perform best, and raw emissions were recorded at several different steady state conditions**.**

The best performing catalyst was the NEX311H1 catalyst, with average NOx values of 0.078 g/bhp-hr over the hot HDT cycle, and a low single run of 0.057 g/bhp-hr. Another benefit of the advanced NEX311H1 catalyst is the greatly reduced Total Hydrocarbon (THC) emissions. While the production catalyst emitted 0.360 g/bhp-hr of THC, the NEX catalyst reduced that number to an average of 0.135g/bhp-hr.

With regards to particulate matter (PM), the goal of this project was to ensure that PM emissions were below 0.01 g/bhp-hr. During the final transient tests of the NEX catalysts, the PM levels measured were 0.0015 g/bhp-hr during the hot runs, and 0.007 g/bhp-hr during the cold runs, easily below the target levels.

Benefits

The benefit of this project is reduced NOx emissions. By simply increasing the cell density of the catalyst substrate of the base gasoline catalysts (thus greatly increasing surface area), it has shown an 85% reduction in NOx. Future projects using even higher cell-density substrates are planned that may further reduce NOx emissions.

Since the majority of heavy duty vehicles in the South Coast Air Basin are powered by diesel engines which produce higher NOx levels and particulate matter, the introduction of this very low NOx CNG engine would greatly reduce overall emissions for this vehicle type. Although it may be possible for diesel NOx emissions to be reduced to the levels currently achieved by CNG engines, their increased cost and reduced fuel economy will lessen the marketability of such a diesel engine. The immediate implementation of low NOx CNG engines is clearly the simplest means of achieving clean air goals.

Project Costs

The total project cost was $233,730US. This includes emissions testing by Bodycote Materials Testing Inc, and labor, travel and administration costs by GFI. AQMD contributed $140,000US to this project.

Commercialization and Applications

The intended application of this engine technology is for medium duty vehicles such as airport shuttle vans, rental car and hotel shuttle vehicles, and small delivery vehicles. With the increasing CNG distribution infrastructure, the viability and practicality of a low NOx CNG engine increases, as do its commercial benefits. With respect to the clean air goals of the South Coast Air Basin, such low emission vehicles are more environmentally attractive than any other commercially viable vehicle on the market today. Further discussions between TeleflexGFI and GM will need to be conducted before additional commercial and costing analysis can be performed.